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CADMIUM PLATING VS. OTHER COATINGS TO PREVENT CORROSION

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The electrodeposited cadmium coating used to prevent corrosion of screws can cause hydrogen embrittlement type failures. Protective coatings applied to screws by processes other than electrodeposition were tested for corrosion resistance (5% salt spray test). The corrosion resistance of cadmium plated screws was significantly superior to the other coatings selected as possible canidates for replacing cadmium.

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STATEMENT OF THE PROBLEM

The steel fasteners used for assembling cannon are usually protected from corrosion by an electrodeposited cadmium coating. The electrodeposition process is known to cause hydrogen embrittlement which can result in an early failure of a fastener. In order to avoid failures caused by hydrogen, protective coatings that are applied by a process that does not involve electricity were tested for corrosion resistance. This report will describe the results of corrosion resistance testing on cadmium and the other selected protective coatings.

BACKGROUND

The majority of fasteners used to assemble cannon are low alloy steel, socket head cap screws that are coated with electrodeposited cadmium. The screws are purchased to either Military Standard (MS) 16998 (fine threads) or MS 16997 (coarse threads). The MS specifications require that the cap screws be produced to the Federal Specification, FF-S-86 (Type VI), which requires that alloy steel screws have a tensile strength of 170 ksi minimum and a hardness of Rc 38-45. The screws produced to FF-S-86 typically are AISI 4140 which is heat treated by quenching in oil and tempered to the Rc 38-45 range. The electrodeposited cadmium plating is in accordance with QQ-P-416, (Plating, Cadmium-Electrodeposited), Type II (supplementary chromate treatment), Class 3 (.0002 inch minimum thickness).

Failures of cadmium plated cap screws have occurred during the past several years. The screws either break during or after the torqueing

operation. Metallographic examinations revealed that the fractures are typically intergranular which is indicative of hydrogen embrittlement. Since the electrodeposition plating process is known to cause hydrogen embrittlement of high strength steel, short and long term actions were initiated to solve the problem. The short term actions that were initiated for preventing failures of cadmium plated screws are as follows: (a) within one (1) hour after cadmium plating, the screws have to be thermally treated for a minimum of twenty-three (23) hours at a 375 ± 25°F temperature, (b) a random sample of four (4) screws from each lot or batch that are cadmium plated and thermally treated are subjected to the stress durability test No. 5 - torque method of loading per MIL-STD-1312 for a minimum of two hundred (200) hours. The induced load is 75 percent of the minimum tensile strength of the screw. After the test, the screws are inspected by the wet, fluorescent, magnetic particle process (MIL-I-6868). The lot fails if any crack is discovered. The long term action was to determine if cadmium could be replaced by a protective coating that is applied by a process that does not cause hydrogen embrittlement. This report provides a description and summary of the testing that was conducted to evaluate the long term solution for preventing hydrogen embrittlement failures of cap screws.

APPROACH TO THE PROBLEM

The protective coatings selected for testing and the testing procedure are as follows:

a. Protective Coatings - Protective coatings were applied to socket

head cap screws manufactured from AISI 4140 alloy steel, heat treated to Rc 38/45. These screws were 3/8"-16-3A, 1-3/4 inches long, that were certified to be in accordance with FF-S-86. The protective coatings that were applied to the cap screws are as follows:

(1) Electrodeposited cadmium with a supplementary bronze chromate treatment per QQ-P-416, Type II (supplementary chromate treatment), Class 3 (.0002 inch minimum). This is the coating presently used for cap screws.

(2) Zinc phosphate per DOD-P-16232 Type Z with a supplementary treatment of oil per MIL-L-3150 (P7).

(3) Electrodeposited zinc with bronze chromate per QQ-Z-325 Type II, Class 3 (.0002 inch minimum). Although this coating is applied by the electrodeposition process, it was decided that testing this coating would be worthwhile since zinc is touted to be equal to or better than cadmium.

(4) Manganese phosphate per DOD-P-16232 Type M, Class 1 with a supplementary coating of solid film lubricant (heat cured, 0.0002 to 0.0005 inch thick) per MIL-L-46010.

(5) Converted manganese phosphate (Endurion) per DOD-P-16232 Type M, Class 4, with a supplementary coating of oil per MIL-L-3150.

(6) Ion vapor deposited aluminum per MIL-C-83488 Type II supplementary (chromate) treatment, Class 3 (.0003 inch thick minimum).

b. Test Procedure - The testing procedure for evaluating the corrosion resistance of the selected protective coatings was the 5% salt spray test per ASTM B117. The coated screws were tested under two conditions - (1) unused and (2) screws were threaded in and out of a one (1) inch thick steel plate three times and removed from the plate. Two (2) screws with each coating subject to each condition were tested. The time in hours required to develop small spots (no specific size) of rust and to develop gross or complete rusting was monitored. Also, the time required to develop any sign of white corrosion products was monitored on the cadmium plated screws.

RESULTS

The results of the 5% salt spray corrosion testing are summarized in Table I. The data reveals that the electrodeposited cadmium coating is an excellent corrosion resistant coating and is significantly superior to all the coatings that were tested if the failure criterion is based upon the time required to generate small areas or spots of rust. If the failure criterion is based upon the time required to generate general (complete) rusting, then the coating of heat cured solid film lubricant applied to manganese phosphate is equivalent to the cadmium coating.

Threading the coated bolts in and out of a steel plate reduced the corrosion resistance. The threading procedure reduced the life of cadmium more than the other coatings, however even after subjecting the cadmium coated bolts to the threading operation, they had more life than unused bolts

with the other coatings based on the failure criterion of small spots of rust.

The manganese phosphate with heat cured solid film libricant coating started rusting relatively soon but, a very large amount of time was required to generate complete rusting. This was also true for the manganese phosphate converted by the Endurion process, but not to the same extent or magnitude as for the phosphate/SFL coating. The Ion Vapor Deposited (IVD) aluminum and zinc phosphate coatings required a large amount of time for rusting to initiate but, rusting proceeded quite rapidly after the initiation period.

The electrodeposited zinc coating started rusting and allowed complete rusting sooner than any of the coatings. This was not expected. However, it is now obvious that zinc is not a good coating to prevent corrosion in a salt, environment.

CONCLUSIONS

a. Electrodeposited cadmium is an excellent coating for preventing corrosion (rusting) of steel bolts.

b. Manganese phosphate with heat cured solid film lubricant (SFL) allows the initiation of rusting after a relatively short period of time, however it will prevent general rusting of the complete item for a long period of time. If the criterion for failure was complete rusting, this protective coating would be equivalent to cadmium.

c. After a coated bolt is threaded in and out of a hole, the corrosion resistance will be significantly reduced for most coatings. The exceptions to this were the electrodeposited zinc and manganese phosphate converted by the Endurion process coatings.

TABLE I

5% Salt Spray Corrosion Test
(Hours to develop corrosion)

PROTECTIVE COATING	UNUSED		THREADED IN/OUT OF STEEL PLATE 3 TIMES	
	Small spots of rust	Complete rusting	Small spots of rust	Complete rusting
Electrodeposited Cadmium w/Chromate	2112	*(4008)	792	2472
(White Corrosion)	48		48	
Zinc Phosphate w/Oil (MIL-L-3150)	336	504	168	504
Electrodeposited Zinc w/Chromate	168	216	168	216
Manganese Phosphate w/SFL	216	*(4008)	72	2112
Endurion Phosphate w/Oil (MIL-L-3150)	408	1128	408	792
IVD Aluminum	432	528	336	528

*Rusting was not complete

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